

CLAIMS

1. An apparatus for combining oxygen and fuel to produce a mixture to be burned in a burner, the apparatus comprising
 - 5 a fuel supply tube formed to include an inlet, an outlet, and a passageway extending therethrough from the inlet to the outlet,
means for moving a stream of fluidized, pulverized, solid fuel fluidized using a fluidizing gas in a downstream direction into the passageway through the inlet and out of the passageway through the outlet,
 - 10 an oxygen supply housing coupled to an upstream portion of the fuel supply tube to define an upstream oxygen chamber therebetween and formed to include an oxygen inlet adapted to admit oxygen into the upstream oxygen chamber, the upstream portion of the fuel supply tube being formed to include an upstream set of oxygen-injection holes opening into the passageway located in the upstream
 - 15 portion of the fuel supply tube,
an outer tube coupled to a downstream portion of the fuel supply tube to define an oxygen flow passage therebetween and formed to include an oxygen inlet adapted to admit oxygen into the oxygen flow passage, the downstream portion of the fuel supply tube being formed to include a downstream set of oxygen-injection holes
 - 20 opening into the passageway located in the downstream portion of the fuel supply tube, and
an oxygen delivery system including first oxygen conductor means for conducting a first stream of oxygen through the upstream set of oxygen-injection holes to mix with fluidized, pulverized, solid fuel conducted through the passageway
 - 25 in the upstream portion of the fuel supply tube to produce an oxygen-enriched, yet not spontaneously combustible, oxygen-fuel transport mixture and second oxygen conductor means for conducting a second stream of oxygen through the oxygen inlet formed in the outer tube and into the oxygen flow passage to pass through the downstream set of oxygen-injection holes to mix with the oxygen-enriched, yet not
 - 30 spontaneously combustible, oxygen-fuel transport mixture conducted through the passageway in the downstream portion of the fuel supply tube to produce an oxygen-

fuel mixture exiting the passageway through the outlet of the fuel supply tube to be ignited outside the passageway to produce a flame.

2. The apparatus of claim 1, wherein the oxygen delivery system further includes means for determining concentration of oxygen in a fluidizing gas used to fluidize the stream of fluidized, pulverized, solid fuel and varying the amount of oxygen conducted through the upstream set of oxygen-injection holes by the first oxygen conductor means after determining the concentration of oxygen in the fluidizing gas to maintain the concentration of oxygen in the oxygen-enriched, yet not spontaneously combustible, oxygen-fuel transport mixture produced in the upstream portion of the fuel supply tube at a not spontaneously combustible level.

3. The apparatus of claim 1, further comprising a refractory shape formed to include a flame chamber receiving the oxygen-fuel mixture exiting the passageway through the outlet of the fuel supply tube and the oxygen delivery system further includes distribution means for varying an amount of oxygen supplied to the passageway located in the upstream portion of the fuel supply tube by the first oxygen conductor means and an amount of oxygen supplied to the passageway located in the downstream portion of the fuel supply tube by the second oxygen conductor means.

4. The apparatus of claim 1, further comprising a refractory shape formed to include a flame chamber having an inlet opening and an outlet opening and receiving the oxygen-fuel mixture exiting the passageway through the outlet end of the fuel supply tube, and wherein the refractory shape is also formed to include a staged-oxygen bypass conduit arranged to receive oxygen conducted by the second oxygen conductor means and to conduct oxygen outside of the flame chamber to the outlet opening of the flame chamber and the oxygen delivery system further includes distribution means for varying an amount of primary oxygen supplied by the first conductor means to the passageway in the upstream portion of the fuel supply tube and an amount of secondary oxygen supplied by the second conductor means to the passageway in the downstream portion of the fuel supply tube and to the staged-oxygen bypass conduit to regulate the relative concentration of the oxygen-enriched, yet not spontaneously combustible, oxygen-fuel transport mixture and the oxygen-fuel mixture so that a selected ratio of primary and secondary oxygen is achieved to optimize emissions generated by burning the oxygen-fuel mixture in the flame

chamber and adjust for variations in physical properties of pulverized solid fuel entrained in a fluidizing gas used to fluidize the fluidized, pulverized, solid fuel.

5 5. The apparatus of claim 1, wherein the oxygen supply housing includes a sleeve having an annular inner surface, the upstream portion of the fuel supply tube passes through a channel defined by the annular inner surface of the sleeve, and an annular exterior surface of the upstream portion of the fuel supply tube cooperates with the annular inner surface of the sleeve to define the upstream oxygen chamber therebetween.

10 6. The apparatus of claim 5, wherein the oxygen supply housing further includes a first end wall coupled to a first end of the sleeve and formed to include a first opening receiving the upstream portion of the fuel supply tube therein and a second end wall coupled to a second end of the sleeve and formed to include a second opening receiving the upstream portion of the fuel supply tube therein, and the annular exterior surface of the upstream portion of the fuel supply tube, the annular inner surface of the sleeve, and inner surfaces of the first and second end walls cooperate to define a boundary of the upstream oxygen chamber.

15 7. The apparatus of claim 6, wherein the sleeve is formed to include the oxygen inlet.

20 8. The apparatus of claim 5, wherein the sleeve is positioned to lie in spaced-apart relation to the outer tube.

 9. The apparatus of claim 5, wherein the sleeve is formed to include the oxygen inlet, the first oxygen conductor means includes a tube coupled to the sleeve at the oxygen inlet to deliver oxygen into the upstream oxygen chamber, and the sleeve and the tube cooperate to define a T-shaped member mating with upstream portion of fuel supply tube.

25 10. The apparatus of claim 1, further comprising a refractory shape formed to include a flame chamber having an inlet opening and an outlet opening and receiving the combustible oxygen-fuel mixture exiting the passageway through the outlet end of the fuel supply tube and wherein the outer tube is positioned to lie between the oxygen supply housing and the refractory shape.

30 11. The apparatus of claim 10, wherein the second oxygen conductor means includes a second oxygen supply housing coupled to the outer tube

and to the refractory shape to define a second oxygen chamber located to allow oxygen extant in the second oxygen chamber to flow into the oxygen flow passage through the oxygen inlet formed in the outer tube.

12. The apparatus of claim 11, wherein the refractory shape is also
5 formed to include a staged-oxygen bypass conduit arranged to receive oxygen flowing out of the second oxygen chamber through an oxygen outlet formed in the second oxygen supply housing and to conduct said oxygen to the outlet opening of the flame chamber.

13. An apparatus for combining oxygen and fuel to produce a
10 mixture to be burned in a burner, the apparatus comprising
a fuel supply system including a solid-fuel conduit formed to include a fuel transport passageway, the solid-fuel conduit including a side wall formed to include oxygen-injection holes opening into the fuel transport passageway, and
first oxygen conductor means for conducting a first stream of oxygen
15 through the oxygen-injection holes formed in the side wall of the solid-fuel conduit to mix with fluidized, pulverized, solid fuel conducted through the fuel transport passageway prior to combustion to produce an oxygen-enriched, not spontaneously combustible, oxygen-fuel transport mixture.

14. The apparatus of claim 13, wherein the first oxygen conductor
20 means includes a first oxygen-supply housing formed to include first and second openings, an oxygen chamber adapted to receive a supply of oxygen, and an oxygen inlet adapted to admit oxygen into the oxygen chamber, and the solid-fuel conduit extends through the first and second openings to place the oxygen-injection holes in the oxygen chamber to allow oxygen extant in the oxygen chamber to flow through
25 the oxygen-injection holes into the fuel transport passageway formed in the solid-fuel conduit.

15. The apparatus of claim 14, wherein the first oxygen supply
housing includes a cylinder-shaped side wall formed to include the oxygen inlet, a first end wall coupled to one end of the cylinder-shaped side wall and formed to
30 include the first opening, and a second end wall coupled to another end of the cylinder-shaped side wall and formed to include the second opening, and wherein the

cylinder-shaped side wall, the first and second end walls, and a portion of the solid-fuel conduit cooperate to define the oxygen chamber therebetween.

16. The apparatus of claim 14, further comprising means for conducting a stream of fluidizing gas into the fuel transport passageway, means for
5 discharging a pulverized solid fuel into the stream of fluidizing gas to produce a fluidized, pulverized, solid fuel flowing through the fuel transport passageway, oxygen supply means for supplying oxygen to the oxygen chamber formed in the first oxygen-supply housing through the oxygen inlet, and means for determining
10 concentration of oxygen in the stream of fluidizing gas and varying the amount of oxygen supplied to the oxygen chamber by the oxygen supply means after determining the concentration of oxygen in the stream of fluidizing gas to maintain the concentration of oxygen in the oxygen-fuel transport mixture produced in the fuel transport passageway upon discharge of the pulverized solid fuel into the stream of
fluidizing gas at a not spontaneously combustible level.

17. The apparatus of claim 14, further comprising an outer tube and
15 wherein the fuel supply system further includes an oxygen-fuel nozzle formed to include an oxygen-fuel transport passageway and coupled to the solid-fuel conduit to receive the oxygen-enriched, not spontaneously combustible, oxygen-fuel transport mixture discharged from the solid-fuel conduit in the oxygen-fuel transport
20 passageway, a portion of the solid-fuel conduit and the oxygen-fuel nozzle extends into the outer tube to define an oxygen flow passage therebetween, the oxygen-fuel nozzle is formed to include oxygen-injection means for admitting a stream of oxygen flowing through the oxygen flow passage into the oxygen-fuel transport passageway formed in the oxygen-fuel nozzle to enrich the concentration of oxygen in the oxygen-
25 enriched, not spontaneously combustible, oxygen-fuel transport mixture extant in the oxygen-fuel transport passageway to establish an oxygen-fuel mixture flowing in the oxygen-fuel transport passageway and exiting through an oxygen-fuel outlet opening formed in the oxygen-fuel nozzle.

18. The apparatus of claim 17, further comprising an oxygen
30 supply coupled to the first oxygen conductor means and second oxygen conductor means for conducting a second stream of oxygen from the oxygen supply into the oxygen flow passage.

19. The apparatus of claim 17, further comprising a refractory shape formed to include a flame chamber having an inlet opening and an outlet opening and receiving the oxygen-fuel mixture exiting through the oxygen-fuel outlet opening formed in the oxygen-fuel nozzle and passing into the inlet opening of the flame chamber, the refractory shape also being formed to include a staged-oxygen bypass conduit arranged to conduct oxygen outside of the flame chamber to the outlet opening of the flame chamber, a second oxygen-supply housing arranged to cooperate with the outer tube to define a second oxygen chamber adapted to receive a supply of oxygen, the second oxygen-supply housing being formed to include an oxygen inlet adapted to admit oxygen into the second oxygen chamber and an oxygen outlet arranged to discharge oxygen extant in the second oxygen chamber into the staged-oxygen bypass conduit, and wherein the outer tube is formed to include a second set of oxygen-injection holes opening into the oxygen flow passage to conduct oxygen extant in the second oxygen chamber into the oxygen flow passage to supply oxygen to the oxygen-injection means formed in the oxygen-fuel nozzle.

20. The apparatus of claim 13, further comprising a refractory shape formed to include a flame chamber receiving the oxygen-fuel mixture produced in the fuel transport passageway and having an inlet opening and an outlet opening, a staged-oxygen bypass conduit arranged to conduct oxygen outside of the flame chamber to the outlet opening of the flame chamber, and second oxygen conductor means for conducting a second stream of oxygen to the inlet opening of the flame chamber and to the staged-oxygen bypass conduit to enrich the concentration of oxygen in the oxygen-enriched, yet not spontaneously combustible, oxygen-fuel transport mixture in the flame chamber to produce an oxygen-fuel mixture in the flame chamber, means for conducting a stream of fluidizing gas into the fuel transport passageway, means for discharging a pulverized solid fuel into the stream of fluidizing gas to produce a fluidized, pulverized, solid fuel flowing through the fuel transport passageway, an oxygen supply, and distribution means for varying an amount of primary oxygen supplied by the oxygen supply to the first oxygen conductor means and secondary oxygen supplied by the oxygen supply to the second oxygen conductor means to regulate the relative concentration of oxygen in the oxygen-enriched, yet not spontaneously combustible, oxygen-fuel transport mixture

established in the fuel transport passageway and the oxygen-fuel mixture extant in the flame chamber so that a selected ratio of primary and secondary oxygen is achieved to optimize emissions generated by burning the oxygen-fuel mixture extant in the flame chamber and adjust for variations in physical properties of pulverized solid fuel discharged into the stream of fluidizing gas.

21. The apparatus of claim 20, wherein the distribution means includes a first oxygen supply tube arranged to conduct oxygen from the oxygen supply to the first oxygen conductor means, a primary oxygen-fuel ratio controller valve associated with the first oxygen supply tube to regulate flow of oxygen from the oxygen supply to the first oxygen conductor means, a second oxygen supply tube arranged to conduct oxygen from the oxygen supply to the second oxygen conductor means, a staged oxygen-fuel ratio controller valve associated with the second oxygen supply tube to regulate flow of oxygen from the oxygen supply to the second oxygen conductor means, and control system means for opening and closing the primary and staged oxygen-fuel ratio controller valves to establish the selected ratio of primary and staged oxygen.

22. An apparatus for combining oxygen and fuel to produce a mixture to be burned in a burner, the apparatus comprising

- a refractory shape formed to include a flame chamber having an inlet opening and an outlet opening,
- a staged-oxygen bypass conduit arranged to conduct oxygen to the outlet opening of the flame chamber,
- a fuel supply tube formed to include an inlet adapted to be coupled to a supply of fluidized, pulverized, solid fuel, an outlet coupled to the inlet opening of the flame chamber, and a passageway extending therethrough from the inlet to the outlet to discharge fuel into the flame chamber,
- a first oxygen supply housing coupled to the fuel supply tube to define a first oxygen chamber, the fuel supply tube being formed to include a first set of oxygen-injection holes to allow oxygen extant in the first oxygen chamber to pass into a stream of fluidized, pulverized, solid fuel passing through the passageway and moving in a direction toward the flame chamber,

a second oxygen supply housing arranged to define a second oxygen chamber and coupled to the staged-oxygen bypass conduit to allow oxygen extant in the second oxygen chamber to pass through the staged-oxygen bypass conduit to intercept any flame produced by ignition of a fuel discharged into the flame chamber from the fuel supply tube,

a first oxygen conductor coupled to an oxygen inlet formed in the first oxygen supply housing and configured to conduct a first stream of oxygen into the first oxygen chamber,

a second oxygen conductor coupled to an oxygen inlet formed in the second oxygen supply housing and configured to conduct a second stream of oxygen into the second oxygen chamber,

a primary oxygen-fuel ratio controller coupled to the first oxygen conductor and configured to regulate flow of oxygen into the first oxygen chamber,

a secondary oxygen-fuel ratio controller coupled to the second oxygen conductor and configured to regulate flow of oxygen into the second oxygen chamber, and

control means for operating the primary and secondary oxygen-fuel ratio controllers to regulate the relative concentration of oxygen in a first oxygen-fuel mixture established in the passageway formed in the fuel supply tube when primary oxygen from the first oxygen chamber flows through the first set of oxygen-injection holes formed in the fuel supply tube to mix with fluidized, pulverized, solid fuel passing therethrough and in an oxygen-enriched oxygen-fuel mixture established by mixing the first oxygen-fuel mixture with secondary oxygen discharged from the staged-oxygen bypass conduit so that a selected ratio of primary and secondary oxygen is achieved to optimize emissions generated by burning an oxygen-fuel mixture extant in the flame chamber and adjust for variations in physical properties of pulverized solid fuel included in the fluidized, pulverized solid fuel.

23. The apparatus of claim 22, wherein the fuel supply tube is formed to include a second set of oxygen-injection holes to allow oxygen to flow therethrough into the passageway formed in the fuel supply tube to mix with an oxygen-fuel mixture passing therethrough and further comprising means for

conducting oxygen extant in the second oxygen chamber into the passageway formed in the fuel supply tube through the second set of oxygen-injection holes.